HIGH PERFORMANCE FLOW BATTERY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Applications Ser. Nos. 61/319,248 filed Mar. 30, 2010 and 61/322,780 filed Apr. 9, 2010, incorporated by reference in their entirety herein.

FIELD OF THE INVENTION

[0002] This invention relates to high performance electrochemical cells and batteries, and more particularly to flow batteries.

BACKGROUND OF THE INVENTION

[0003] The "greening" of the energy economy, increasing demand and use of renewable energy sources such as wind and solar, and the expected proliferation for example of plug-in hybrid vehicles and all electric vehicles, increasingly strain the electricity distribution grid. High capacity electrical energy storage technologies such as pumped hydroelectric can play an important role in grid load balancing, time shifting renewable energy sources from time of generation to peak time of use, however, geography and cost limit their use, particularly on a local level.

[0004] Existing high capacity battery technologies, for example flow batteries, are too expensive for widespread adoption because the effective cost of the resulting energy and/or power delivered is well above market prices. There exists therefore a substantially unmet need for a low-cost, high-capacity, efficient and high performance battery technology.

SUMMARY OF THE INVENTION

[0005] Embodiments of the present invention provide high performance flow battery apparatus and methods for enhancing, charging, operating and using flow batteries. High current density charging rates and discharging rates in the range of approximately 70 to 400 mA/cm^2, and more particularly in the range of 100 to 250 mA/cm^2, are provided by various embodiments of the present invention.

[0006] Embodiments of the high performance, alkaline zinc/ferro-ferricyanide rechargeable ("ZnFe") flow batteries of the present invention are based on a number of improvements over the prior art. These embodiments are also applicable to other flow batteries that incorporate the plating of a metal to store energy (such as: ZnHBr; ZnBr; CeZn; and ZnCl).

[0007] First, the battery design has a cell stack comprising a low resistance positive electrode in at least one positive half cell and a low resistance negative electrode in at least one negative half cell, where the positive electrode and negative electrode resistances are selected for uniform high current density across a region of the cell stack—that is with a resistance across the electrodes sufficiently low to ensure small voltage variations across the electrode and hence uniform current flow out of the electrode and across the cell stack.

[0008] Second, a flow of electrolyte (for example, zinc species in the ZnFe battery) with a high level of mixing (also referred to herein as a "high rate of mixing" and "high mixing") through at least one negative half cell in a Zn deposition region proximate a deposition surface where the electrolyte close to the deposition surface has sufficiently high zinc concentration for deposition rates on the deposition surface that sustain the uniform high current density. The electrolyte flow and mixing of the flow in the negative half cell are engineered to provide a mass transfer coefficient sufficient to support the high current density and to provide substantially uniform deposition of, for example zinc, over the deposition surface of a cell. Furthermore, some embodiments have been flow engineered to provide zinc deposition at less than a limiting current, where the deposited zinc has a dense, adherent, non-dendritic morphology.

[0009] Third, the zinc electrolyte has a high concentration and in some embodiments has a concentration greater than the equilibrium saturation concentration—the zinc electrolyte is super-saturated with Zn ions. Different embodiments of the present invention combine one or more of these improvements.

[0010] Electrolyte flow with high mixing through the cell may be due to high fluid velocity in a parallel plate channel. However, the mixing in the flow may be induced by structures such as: conductive and non-conductive meshes; screens; ribbons; foam structures; arrays of cones, cylinders, or pyramids; and other arrangements of wires or tubes used solely or in combination with a planar electrode surface. Use of such structures may allow for high mixing of the electrolyte with laminar flow or with turbulent flow at high or low fluid velocity. Furthermore, structures for calming the turbulent flow may be included in the electrolyte fluid circuit immediately after the cell.

[0011] According to embodiments of the present invention, methods for operating a flow battery may include flowing electrolyte with high mixing in a laminar flow regime, or turbulent flow regime, through at least one negative half cell in a Zn deposition region proximate a deposition surface. Furthermore, some embodiments include depositing Zn with a dense, adherent, non-dendritic morphology. The high mixing flow may be utilized during charging and/or discharging of battery cells.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] These and other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures, wherein:

[0013] FIG. **1** is a schematic diagram of a zinc redox flow battery;

[0014] FIG. **2** is schematic diagram of a zinc redox flow battery, according to some embodiments of the present invention;

[0015] FIG. **3** is a schematic perspective view of a flow cell, according to some embodiments of the present invention;

[0016] FIG. **4** is a schematic perspective view of the cell of FIG. **3** contained within a frame, according to some embodiments of the present invention;

[0017] FIG. **5** is a schematic cross-sectional representation of a first example of cell configurations for a redox flow battery, according to some embodiments of the present invention;

[0018] FIG. **6** is a schematic cross-sectional representation of a second example of cell configurations for a redox flow battery, according to some embodiments of the present invention;